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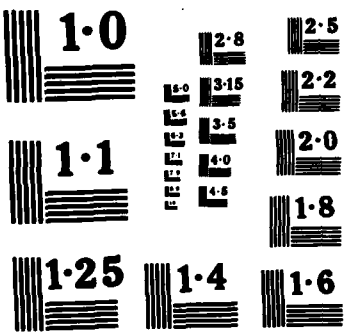

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ARMY REQUIREMENTS FOR DIGITAL TOPOGRAPHIC DATA

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ABSTRACT

The Engineer Topographic Laboratories (~~ETL~~) recently completed a two year study which assessed the digital topographic data (DTD) needs of the US Army. The study identified the Army's DTD requirements for tactical terrain analysis, the Army analysis community, and for known and anticipated Army systems/programs. The overall objective was to define Army DTD requirements for the Defense Mapping Agency (DMA) in order to allow them to consolidate their work efforts and to plan their future production requirements. Both subjective and analytical evaluations were performed using two DMA prototype data sets, with investigations focused on the data sets abilities to support terrain analysis, the analysis community, and existing and emerging Army systems/programs covering tactical, combat modeling, simulation, training, testing, and developmental applications. In addition, the existing or anticipated DTD requirements of Army systems, or programs were documented, summarized and evaluated. These DTD requirements were defined and evaluated in terms of data content, accuracy, resolution, and format, and a data base specification for DTD, encompassing the Army requirements for terrain analysis, and all other system/programs, was prepared to provide a total Army requirement for DTD.

INTRODUCTION

Increasing demand exists throughout the Army for comprehensive DTD to support known and anticipated systems and programs. Previously, Army needs for DTD remained undefined due to a lack of stated/validated requirements in developing Army systems. However, in the past several years, knowledge and use of DTD expanded within various Army systems and programs to the point that users realized the capabilities and benefits of using DTD to provide timely, accurate, and complete information in support of decision making, planning and combat operations. Increasing demand for DTD occurred within the Army on a system by system basis which resulted in individual users and developers beginning to define specific DTD requirements. However, these DTD requirements were being developed independent of one another, were similar enough in nature to warrant concern over duplication of efforts, and were not supportable by DMA. Developing separate data bases to support individual Army systems or programs is not only redundant and costly, but also effects an inefficient utilization of DTD production resources. This inefficiency endangers the full development of the rapidly expanding DTD technology by creating an increased workload for DMA. The best and most cost effective solution, therefore, is to satisfy the DTD requirements of many systems/programs with a single, unified data base. To address this challenge, the Department of the Army (DA) requested that DMA develop a prototype digital terrain data set which the Army could then evaluate with its overall DTD needs. The intention was to determine if a single DMA product could support the combined needs of a number of Army agencies and, if so, define these needs together. In response to the DA request, DMA agreed to produce two digital terrain data

prototypes and officially requested the Army develop a plan to evaluate these data sets. DA also requested that the plan include the identification of all known and anticipated Army systems/programs which are, or will be, requiring DTD.

Through a series of command taskings, ETL was appointed the lead agency in developing and in conducting the Army's overall DTD evaluation plan. The plan had three objectives. The first objective was to investigate and to assess the adequacy of the two DMA prototype data sets in supporting tactical terrain analysis. The second objective was to identify and to articulate the known and the future requirements for DTD in existing and emerging tactical systems, combat models, simulators, training devices, and operational displays. Both of these objectives focused on the data content, accuracy, resolution, and format necessary to successfully meet the Army's needs, and constituted the Army's requirements analysis process. The third and final objective was to consolidate the large variety of known and anticipated Army DTD requirements into a single, unified statement formulated as a specification for a digital topographic data base which could support as many Army users as possible.

The Army's evaluation plan, as developed with the three objectives mentioned above and as approved, was a two-phased DTD requirements assessment. Phase I mainly addressed the Army's terrain analysis requirements for DTD and was conducted primarily at ETL. Phase II concerned both known and anticipated near- and long-term requirements for fielded tactical systems and also for the Army's simulation, modeling, and training activities. The requirements of the Army's analysis community were addressed in both phases of the evaluation plan. The DTD requirements evaluation within the Army analysis community was the responsibilty of the Army's Training and Doctrine Command's System Analysis Activity (TRASANA) and covered the data requirements for existing and developing combat models, simulators, and training devices. The Army analysis community comprises the Operations Research and Systems Analysis (ORSA) cells within the Army's various proponent schools, major Army commands' systems analysis agencies, and several Army research elements. The analysis community's requirements were evaluated independently from ETL's evaluation efforts; however, ETL closely coordinated with TRASANA and was ultimately responsible for integrating the analysis community's part of the Army's evaluation into the overall report. The combined needs from both phases yielded a total statement of Army DTD needs, which, coupled with a cross-comparison with the two DMA prototype data sets, allowed for the preparation of the digital topographic data base specification which describes the Army's requirements. Each phase of the Army's plan is discussed below.

PHASE I

To evaluate the Army's terrain analysis requirements for DTD, the adequacy of each of the DMA prototype data sets was assessed in terms of data content completeness, absolute and relative accuracy (vertical and horizontal), resolution of the elevation and feature data, and the format or structure in which the data are recorded (including the coordinate systems and reference datums). That is, were the prototypes of sufficient accuracy and resolution and did they have sufficient data content to be adequately utilized for tactical terrain analysis and thus support Engineer Terrain Teams in their duties? These terrain analysis requirements for DTD result from the development of automated

terrain analysis capabilities which are being designed to help the Army meet the urgent demand for timely, comprehensive, and accurate information about the military aspects of terrain to support decision making, mission planning, and combat operations. Such capabilities are an integral part of the Army's current doctrine. Many of these automated terrain analysis capabilities have already been demonstrated in ETL's Geographic Sciences Laboratory where the Digital Topographic Support System (DTSS) is under advanced development. The DTSS is a battlefield system which will provide Engineer Terrain Teams the capability to produce complex terrain products in a quick, automated mode as opposed to the time-consuming, manual process of today.

The DTSS and other future battlefield systems will require accurate digital topographic data to operate. Recognizing that these data will be provided by DMA, Phase I of the Army's evaluation focused on determining how well the two DMA prototype data sets could support digital terrain analysis. This evaluation, conducted at ETL, was aided by the use of an in-house, commercial interactive graphics system called the Digital Terrain Analysis Station (DTAS). The DTAS is a research and development program designed to automate tactical terrain analysis from digital sources through software development.

To evaluate the two DMA prototype data sets' ability to support terrain analysis requirements, software routines were developed to read and reformat the DMA data into the DTAS data base. With the DMA prototype data sets reformatted for the DTAS, terrain analysis models or products (e.g. cross country mobility, concealment, river crossing, terrain profile, masked area, etc.) developed as part of the referenced R&D software development program, were executed using both DMA prototype data sets as input. These products were then compared to manually prepared products produced for the evaluation. These manual products were hand-compiled from DMA-supplied data feature overlays using DMA accepted terrain analysis, synthesis, and modeling techniques.

Operational suitability, in terms of the usefulness and the acceptability of the prototype data element features and the automated terrain analysis products, was determined by visual analyses conducted by the Terrain Analysis Center at ETL, with support from military terrain analysts. Statistical evaluations of both the DMA prototype data element features and the automated terrain analysis products from each data set were performed to objectively compare and to quantify the differences between the digital and the manual data features and products. The accuracy of the elevation data from both prototypes was also evaluated statistically, using a second-order ground truth survey as control. The visual and statistical evaluations also included data degradation analyses to determine the minimum acceptable resolution which could satisfy Army requirements. To provide further validity to the overall Phase I evaluation, ground truth exercises were conducted by ETL for field verification of the elevation data, the data element features, and the synthesized terrain analysis products.

The evaluation of the suitabilty of the DMA prototype data sets for combat modeling, simulation and training systems within the Army analysis community was the responsibilty of TRASANA, and included input on mobility from the Army Corps of Engineers Waterways Experiment Station. TRASANA's efforts were primarily accomplished using the DMA prototype data sets in their current modeling and simulation programs. The results were reviewed and the suitability of the prototype data sets to support these modeling and simulation programs was determined by analytic comparisons of the resultant products. Finally, a review

of the terrain analysis and Army analysis community requirements with respect to the data content that should be present within a digital data set was conducted and the results compared to the data content from the two DMA prototype data sets. Thus the Army's specification for DTD requirements includes the data content necessary for both terrain analysis and the analysis community.

PHASE I RESULTS

For the most part, the Army's tactical terrain analysis, requirements for DTD, as well as those requirements for the analysis community, can be satisfied with digital products (both elevation and feature data) derived from and comparable to the content, accuracy, and resolution of 1:50,000 scale equivalent sources and products. The DMA specifications for their prototype data sets could support these requirements; however, potential deficiences do exist in data, accuracy, resolution, and format as well as in data feature content. As the availability of acceptable DTD increases, Army terrain analysts, working with maps, charts and other sources, will still have to take changes into account. Even after automation, troops in the field will still need to update and revise terrain data to reflect current conditions. The soldiers who man the topographic units of the future must also be equipped to create new terrain data bases should they be called upon to support combat operations in areas for which DMA data are not available.

PHASE II

Phase II of the Army's evaluation of DTD requirements, for known and anticipated tactical systems and other systems (simulation, modeling, training), was a coordinated effort among the Army's major commands, research facilities/laboratories, proponent schools, analysis groups, and project/system managers. Requirements for the Army analysis community were also addressed. Known Army requirements for DTD are those which have been stated in specific system and program requirement documents or have been validated for support from DMA. Anticipated Army requirements apply to those Army activities which foresee the use of DTD as either an integral or supporting part of their system or programs under development. Generally, specific requirements for DTD relating to these activities have neither been officially stated nor validated by DA. These future requirements encompass emerging tactical systems, combat models, simulators, training devices, aviation tactical mission training devices, cockpit displays, operational displays, and terrain analysis.

Phase II of the Army's evaluation plan was directed towards identifying and articulating known and anticipated DTD requirements of Army systems and program offices, in both the near-term (two year) and the long-term timeframes and was accomplished concurrently with Phase I of the Army's evaluation effort. As with Phase I, contractor support was used to assist in this evaluation effort. Liaison was established with all identified potential Army DTD users through a literature search and by ETL telephone and letter correspondence. A questionnaire was then developed to assist participating Army activities in identifying DTD requirements for their systems. The questionnaire was mailed to each activity and on-site interviews were scheduled. During these on-site interviews, an understanding of the system's or programs's specific requirements for DTD was obtained from those developers who could clearly articulate their needs. In many cases, the interviews served to educate the developers about the use of DTD and about ways in which

they can determine their requirements for these data in the future. Based upon the completed questionnaires and the on-site interviews, individual summaries for each identified Army system/program were prepared. These summaries identify each system or program by name and present the key findings on their individual DTD needs. Each summary also provides a description of the system/program, it's status and applicable military functions, and lists available documentation. Also included in the summaries are details on both terrain elevation and feature data requirements as well as information relating to the on-site visits. A system summary verification process followed to ensure that the summaries accurately reflected the viewpoint of the respondents. Once verification and validation of all system/program data was accomplished, the DTD requirements were organized into a workable format for final evaluation by dividing these data into three categories of systems/programs: 1) tactical, 2) simulation, training, test, and development, and 3) analysis community. DTD requirements matrices were then constructed for each category, and the four main evaluation criteria for both terrain elevation and feature data (data content, accuracy, resolution, and format) were evaluated systematically. In addition, an analysis was performed of system/program functions requiring DTD to determine the types of applications that will utilize the data. Geographic coverage and data requirements were summarized across all systems/programs to obtain an overall, general picture of data volumes and production requirements.

PHASE II RESULTS

Army systems/programs were identified that either require or anticipate a requirement for Digital Topographic Data. In general, these systems and programs requirements for content, accuracy, and resolution exceed the specifications for standard products currently produced by DMA. The majority of Army organizations stated DTD requirements based on current or developing systems and programs. Many potential Army users had neither used terrain elevation nor feature data in digital form. Therefore, requirements were often stated in reference to analog map products. In the event DTD had been utilized previously, terrain elevation data from DMA or another source was most often the type used.

There existed a great variation in the degree of specification with which Army users were able to articulate their requirements. Often, the degree of specification closely corresponded to the level of development of the system or program. Efforts at a more advanced level of development had a better idea of their supporting DTD requirements than efforts just beginning development. Nevertheless, very few systems/programs have conducted error budget analyses or other studies to derive data base requirements. Clearly, monitoring all Army systems and programs with stated requirements will be important as the developmental process continues.

Examination of accuracy and resolution parameters for DTD did not yield a clear-cut specification for a digital topographic data base. In general, specifications for 1:50,000 scale equivalent topographic maps and terrain analysis studies are sufficient to support most Army users. However, there are some very strict accuracy and fine resolution requirements stated by several Army users, and these requirements may need to be accomplished by the producers of a digital topographic data base. Among these stringent requirements, tactical systems and programs involve worldwide data coverage while simulation, training,

test and development efforts typically require data for test sites or other small geographic areas.

A comparative analysis between the resultant DTD requirements of the Phase II evaluation and the two DMA prototype data sets indicates that generally, requirements for the majority of Army DTD users could be satisfied by the current DMA prototype specifications once deficiencies present in the data feature content and also the data accuracy, resolution and format are corrected.

OVERALL RESULTS AND RECOMMENDATIONS

As previously stated, one objective of the Army's DTD evaluation plan was the consolidation of the results of both the Phase I and Phase II evaluations into a single Army statement or specification of DTD requirements. This Army specification is based upon the analysis and evaluation of DTD requirements in support of tactical terrain analysis and the Army analysis community. The specification is also based upon an analysis of system/program DTD requirements applicable to all identified Army systems/programs users.

Through the requirements analysis, conducted as part of the Phase I and the Phase II evaluations, a set of recommendations were derived in the form of a prescribed specification for a digital topographic data base to support Army users. The strictest requirements of the known and anticipated Army systems/programs identified, particularly for data accuracy and data resolution, were carefully analyzed using the following criteria:

- What are the applications for which DTD will be used?
- Have DTD been used in prior efforts?
- What is the status of the system or program?
- What type of system or program is it? (tactical, simulation, training, test and development, etc.)
- What are the data coverage requirements of the system or program?

Based on these criteria, a determination was made on whether the strictest requirements were capable of "driving" an eventual data base specification toward very accurate or high resolution levels. Each of the systems/programs containing stringent requirements were analyzed in this fashion. The final product of this analysis was a recommended specification for terrain elevation data (and their component parts) as well as for feature data and their component parts.

The merging of results from the two-phase evaluation indicated that the majority of Army user community requirements, specifically most tactical applications (including terrain analysis) and these applications of the Army analysis community, can be satisfied with digital products (elevation and feature data) roughly equivalent to the 1:50,000 scale specifications for standard topographic maps/terrain analysis products. That is, digital data derived from and comparable to the content, accuracy and resolution of 1:50,000 scale sources. The DMA prototype data sets, with modifications, could potentially support these requirements.

Requirements for simulation, training, test and development applications are generally much more stringent, as are a few of the tactical and analysis community programs. These applications require accuracy,

and resolution for terrain, elevation, and feature data at significantly higher levels than 1:50,000 scale sources. The requirements can be met with 1:12,500 scale, equivalent specifications; however these specifications exceed those of both DMA prototype data sets.

For the reasons stated above, the Army's specifications for DTD requirements are stated at two levels. This two level description, which applies only to the accuracy and resolution of terrain elevation and feature data requirements, is explained in the Army Specification and is summarized briefly below:

Level I is comprised of digital data set relatively equivalent to a class B, 1:50,000-scale topographic map/terrain analysis study. This data set will support most of the Army's DTD requirements and therefore, the majority of the identified Army systems/programs.

Level II is a data set comparable to a class B, 1:12,500-scale topographic map/terrain analysis study. All Army DTD requirements, with a few exceptions, are met by the Level II data, and for the most part, requirements for Level II data within the Army are for very small geographic areas.

The Army's recommended digital topographic data base specifications are stated at relatively high levels. Items such as file characteristics and feature identification codes are not detailed in the manner of typical DMA digital data base specifications. However, general recommendations on format are discussed. The specifications are designed to provide guidelines for the production of digital products to support various Army weapons systems and other Army applications. As such, the specification will serve to assist DMA in its development of DTD products to serve the Army and other military users.

CONCLUSIONS

There is a growing requirement throughout the Army for digital topographic data, and the need for DTD will certainly increase as greater use of digital processing is introduced into Army systems. This increased need will be both in terms of the number of systems using the data and the degree of data content, accuracy, and resolution required. Formats must be standardized to the largest extent possible and intermediate transformations not accommodated by DMA must be resolved within the Army. The consideration of these needs is not only critical, but DMA's capability to support them must be clearly defined. In many cases, the support capability of DMA has been assumed by the proponent developer without any consideration for the considerable amount of time and resources required to produce DTD products. Such a situation can dangerously lead to fielded systems that cannot be supported. Therefore, system developers must be provided with DTD specifications that meet their requirements and can be realistically supported by DMA. A continued effort will be required to insure that emerging systems requiring DTD can be supported, and DMA must be kept advised of new requirements as they emerge if the end result is to be a true force multiplier in support of the field Army.

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DISCLAIMER

This paper is not to be construed as an official Department of the Army position.

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